Concrete Technology

* Concrete fundamental Principle:

- → Nature, physical and chemical properties, (Ingradient (cement, sand, aggregate, water and with or without admixture)
- → Grade of concrete, concrete mix, test of concrete
- → workability of concrete, factors affecting strength of concrete
- → Mixing, transportation, placing, Compaction, curring, finishing of concrete
- → Admixture
- → High strength concrete
- → Pre-stress concrete

Concrete Ingredient, Physical and chemical Properties of Concrete:

Concrete: Binding medium + Aggregate + Admixture (if required)

- Binding medium → Cement + water
- Aggregate → (70-75)% by weight
- Admixture (if required) → Gypsum + other (it enhances the Properties of Concrete)

In General,
- Cement + water → (14-21)% by weight
- water → (7-15)% by weight

- → water is 0.4 times weight of concrete
- → water is measured in w/c ratio.

w/c ratio → varies from : 0.38 – 0.6

out of total water:
- → 0.23 hydration of cement
- → 0.17 remains in the voids of concrete

= 0.4

→ Concrete gains strength due to hydration of cement.

Cement:

i) Hydrulic cement
   ↳ after mixing with water; cements starts reacting; hydration or hardening starts
   ↳ used for fast construction process

ii) Non-hydrulic cement
   ↳ after mixing with water, hardening starts after drying e.g. lime concrete, mud motar
   → slow construction process

Cement + water $\xrightarrow[\text{Exothermic Process}]{\text{Hydration}}$ Bouge's compound ↓ $\{C_3S, C_2S, C_3A, C_4AF\}$

Bouge's Compound

i) C_3S → Alite → Tri-calcium Silicate
   ↳ (25-30%) by weight
   ↳ Provides early or initial strength within 28 days.
   ↳ generates high heat of hydration
   ↳ Reaction rate is moderate

ii) C_2S → Belite → Di-calcium Silicate
   ↳ (20-45%) by weight
   ↳ ultimate or final strength development (28days to 1year)
   ↳ low heat of hydration
   ↳ slow reaction rate.

iii) C_3A → first compound to react with water
   → Aluminate → Tricalcium Aluminate
   → high heat of liberation/hydration
   → low strength.
   → early setting

iv) C_4AF → ferrite or Tetra-calcium Alumina ferrite
→ Passive compound, low strength
→ reaction rate : moderate
→ Head liberation or head of hydration : moderate

C_3A, C_3S, C_4AF, C_2S → Decrease in heat generation.

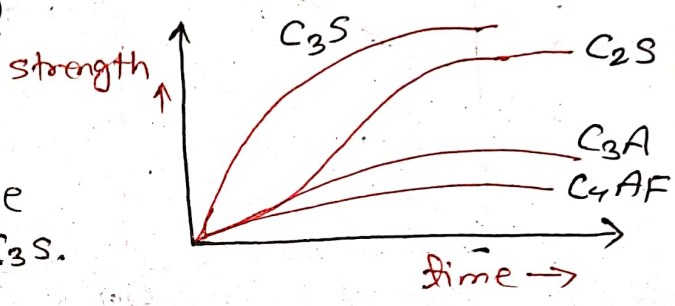
Bouge's equation :

$C_3S : 4.07(C) - 7.60(S) - 6.72(A) - 1.43(F) - 2.85(\bar{S})$

$C_2S : 2.87(S) - 0.754(C_3S)$

$C_3A : 2.65(A) - 1.69(F)$

$C_4AF : 3.04(F)$



→ C_2S has greater resistance to chemical attack than C_3S.

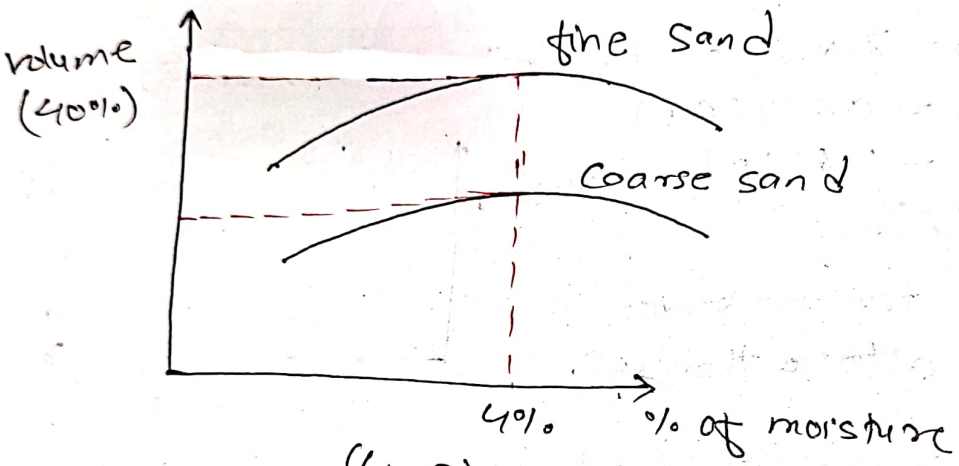
Compound	Composition in %
CaO (C)	60 - 65 %
SiO_2 (S)	17 - 25 %
Al_2O_3 (A)	3 - 9 %
Fe_2O_3 (F)	0.5 - 6 %
O (H)	0.5 - 4 %
SiO_2 ($\bar{S}$)	1 - 2 %
Alkalis (Na_2O, K_2O)	0.4 - 1.3 %

Note
Initial setting time = 30 min.
mixing, transportation, placing, compaction, finishing, should be done within Initial setting time of cement
↓
30 min
↓
within workable concrete
↓
Plastic concrete, green concrete
↳ Target strength meet

* Aggregate

→ fines [sand] → Bulking of sand [Due to surface moisture]
↓ volume increase
fine / coarse sand
(fines modulus)

→ Coarse (aggregate)
↓ max. nominal size of aggregate



(4-5) % Peak

→ 15 cm cube mould (40mm down aggregate)
→ 10 cm cube mould (20mm down aggregate)

↓
Siere Analysis ← grading

40mm (siere) → 100 % Pass
20mm → 30mm → 20 % Pass

→ well graded ⇒ Best compaction.
↳ zero void concrete

Sand, aggregate are inert material
↓
filler material.

Concrete Properties :

1) Plastering concrete
   - freshly mixed, green concrete
   - Ability to move (flow) within initial setting time

Batching → mixing (Dry + wet) → Transportation → Placing → Compact → finishing → Curing

Hardened concrete

- workability of concrete
  (slump test, compaction factor test, flow table test, vee-bee test)
- No segregation
- No bleeding
- Harshness of concrete

2) Hardend concrete
   - ~~*~~ compressive strength (Cube test, Cylinder test)
   - ~~*~~ Bond strength, Shear strength,
   - ~~4)~~ Durability
   - ~~5)~~ Creep
   - ~~6)~~ shrinkage
   - ~~7)~~ modulus of elasticity of concrete
   - ~~8)~~ modulus of rupture
   - ~~9)~~ Poission ratio

Hadened concrete's Disadvantage :

- Tensile strength is approx. $(1/10)^{th}$ of its compressive strength.
- On drying of concrete, shrinkage / crack appears

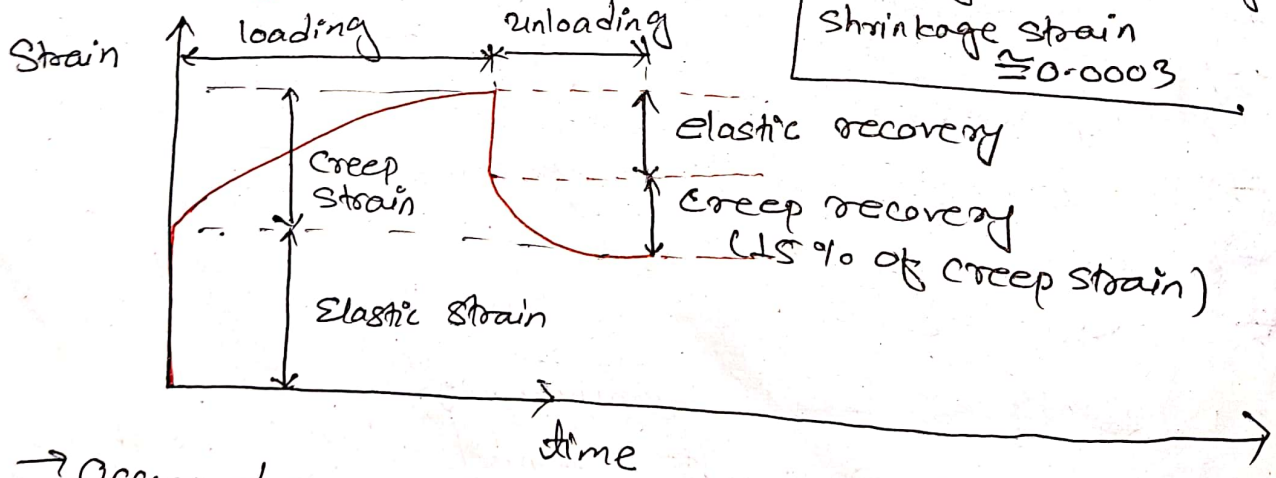
Q. Strain/deformation in concrete at zero stress/force is called
(a) Creep (b) Shrinkage (c) Relaxation (d) None

Q. Strain in concrete at constant stress is called
⇒ Creep.

Shrinkage of concrete: (zero stress condition)
→ Occurs due to drying of fresh concrete (moisture elimination)
⇒ If water cement ratio is more, then shrinkage is more.
→ If aggregate size increased, shrinkage decreases
→ In light weight concrete, higher shrinkage,
→ Relative humidity increases, shrinkage decreases.
→ Shrinkage decreases non-linearly with age.
→ 2 weeks = 75% of total
3 months = 80% of total
1 year = 85% of total

→ Shape & sizes:
Surface area ↓ → water loss ↓, thin member ⇒ higher shrinkage.
Shrinkage strain ≅ 0.0003

Creep of concrete:



→ Occurs due to static/constant loading
→ long term mechanism/time dependent deformation.

→ Creep $\propto \frac{1}{\text{richness}}$ ie. richer the mix, less creep

→ Aggregate with higher modulus of elasticity shows less creep, light weight aggregate shows higher creep.

→ creep decreases with delay in loading,

→ Curing reduces creep in concrete

→ finer the cement, higher creep

→ Higher load, higher creep.

Age of loading	creep coefficient (ϕ)
7 days	2.2
28 days	1.6
1 year	1.1

Relaxation:

→ Reduction in stress at constant strain,

Durability:

→ Ability to resist weathering action, chemical attack, abrasion or any other process of deterioration.

Affecting factors:

a) Permeability

→ high permeability ⇒ low durability

→ dense concrete has low permeability,

→ high w/c ratio, high permeability,

→ with age, permeability decreases

→ If porous aggregate is used, permeability increased,

→

b) Acid attack
→ formation of acids from SO_2, CO_2 present in atmosphere
→ Degree of attack increases as acidity increases.
→ attack occurs below PH about 6.5,
PH less than 4.5 → leads severe attack.
→ In general, PH of concrete is 10.5 to 13.

c) Carbonation
→ Process by which CO_2 from the air penetrates into concrete and reacts with Calcium hydroxide to form Calcium carbonate.
→ Results in small shrinkage

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$$

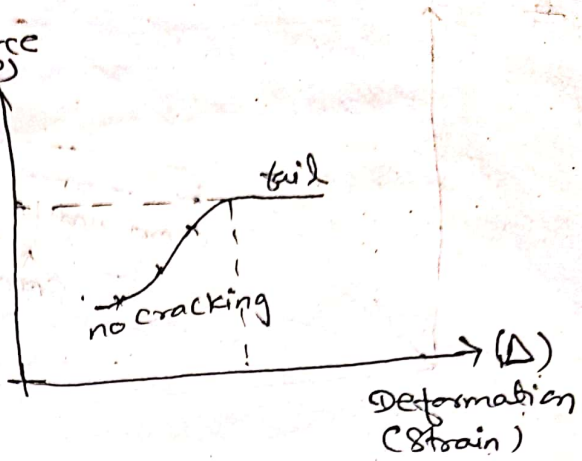
→ Passivity: high alkaline condition which prevents corroding.

d) Alkali-Aggregate Reaction
→ chemical reaction involving alkali and hydroxyl ions from cement paste
→ leads to loss of strength & elastic modulus

factors influencing:
→ Alkali content not more than 3kg/m³ doesnot cause expansion to occur.
→ Cement containing more than 0.6% Na_2O when used can cause significant expansion if alkali reactive aggregate is present

Modulus of elasticity (E_c)

→ P – Δ effect
- P ↓ proving ring
- Δ ↘ dial gauge



→ Brittle material: fails suddenly without any warning sign.
↓
more risk to life
↓
more factor of safety is used

$$E_c = \frac{\text{Stress}}{\text{Strain}}$$

→ $E_c = 5000\sqrt{f_{ck}}$: IS 456 – 2000
↓
MPa [N/mm^2]

→ $E_c = 5700\sqrt{f_{ck}}$: IS 456 : 1978
↓
Short term static modulus of Elasticity
↓
Empirical formula from IS code

E_{ce} = long term modulus of elasticity of concrete.

$$E_{ce} = \frac{E_c}{1+\theta}$$, θ = creep coefficient, depends on age of loading

Q. E_{ce} for 7 days = ?, for M20 concrete.

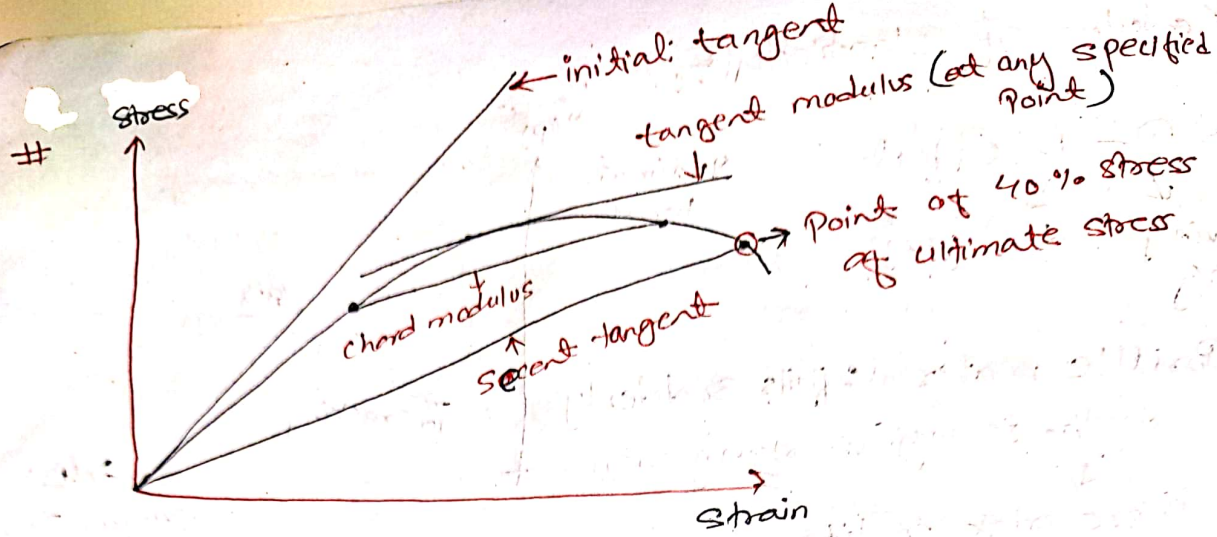
$$E_{ce} = \frac{E_c}{1+\theta} = \frac{5000\sqrt{f_{ck}}}{1+2.2}$$

→ $\frac{5000 * \sqrt{20}}{3.2}$

$E_{ce} = \theta$ ——

3 days	7 days	21 days	28 days
0.4	0.65 (2/3)	0.9	1

* $M_{20} = 0.4 * 20 = 8$ MPa in 3 days.



Dynamic modulus of elasticity [Ed]:

$$E_d = K * n^2 * L^2 * S$$

K → constant, for cylindrical specimen; K = 1
L → length of sample
S → mass density
n → resonate frequency

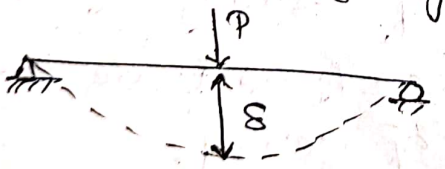
$$E_d = \frac{S * V^2}{K}$$

$$V = L/t$$

, measured using machine called transducer
→ transducer release & receive wave to measure.

$E_c = 1.25\,E_d - 19$ for normal weight concrete

$E_c = 1.04\,E_d - 4.1$ for light weight concrete



flexural modulus of elasticity $(E) = \frac{PL^3}{48\,I\,\delta}$

Possion's Ratio:

If measured by Static method : $\mu = 0.15$ to 0.2

Dynamic method ने measure केला : $\mu = 0.2$ to 0.25

Q. Due to creep effect in concrete, effective modulus of elasticity of concrete will

a) Constant b) Increase c) Decrease d) All

$$E_{ce} = \frac{E_c}{1+\theta}, \quad \theta \uparrow, \; E_{ce} \downarrow$$

Q. Effect of creep on modular ratio (m) of concrete will be

a) Constant b) Increase c) Decrease d) All

$m = \left(\frac{E_{steel}}{E_{concrete}}\right)$ → Constant on steel, no effect

Theoritical value of creep ↓, decrease in $E_{concrete}$ due to creep effect.

$$m = \frac{280}{3 \times 6_{cbc}}$$

↓

Emperical formula.

Grade of Concrete

→ Compressive strength of hardened concrete

classification of grade of concrete (IS 456 : 1978)

1) Ordinary concrete : Nominal mix of concrete in which no preliminary test is carried out.

M10 (1:3:6) M20 (1:1.5:3)

M15 (1:2:4) M25 (1:1:2)

2) Controlled Concrete : Mix design of concrete in which preliminary test is carried out

→ M10, M15, M20, M25, M30, M35, M40

↓ ratio not fix.

As per IS 456:2000,

1) Ordinary concrete : Nominal mix in which proportion of concrete in gradients are pre determined.

→ M10 , M15 , M20

(1:3:6) (1:2:4) (1:1.5:3)

M20 → N/mm² or MPa

2) Standard concrete

→ Mix design should be carried out.

M25, M30, M35, M40, M55, M50

3) High strength concrete

→ M60, M65, M70, M75 M80

↳ min. grade to be used

ACI में

M10 → kg/cm²

Note :

→ Min. grade of concrete used in RCC construction = M20

→ Min. grade of concrete used in pretension pre-stressed concrete = M40

→ Min. grade of concrete used in post-tensioned pre-stressed concrete is M35.

Concrete Mix:

1) Nominal mix :→ Proportioning of concrete ingredients are specified (Pre-determined)
→ M10 (1:3:6), M15 (1:2:4)
→ No guarantee to achieve required strength [Cube test shall be carried out]
→ used only for minor concreting work.

M15 : for 7 days
3 No.s of cube लिये
↓
7th day पर compression test करें
↓
$F_{cm} \rightarrow \frac{(1+2+3)}{3}$ cube

$F_{cm} \geq 0.65 * 15$ MPa

for 3days
3 No.s of cube लिये
↓
Compression test
↓
$F_{cm} = \frac{(1+2+3)}{3}$ cube

$F_{cm} \geq 15$ MPa.

F_{ck} → for mix design
F_{cm} → for nominal mix

Note:
→ Strength of cement is best from manufacture date to within 3 months.
→ with passage of time, strength of concrete decreases.

Q. Percentage of void in cement is approximately
(a) 20 % (b) 30 % (c) 40 % (d) 50 %

Q. Cement becomes useless when it absorbs moisture contents :
a) 5 % b) 10 % c) 15 % d) 20 %

2) Mix design

→ The process of determining relative proportions of concrete ingredients to achieve:

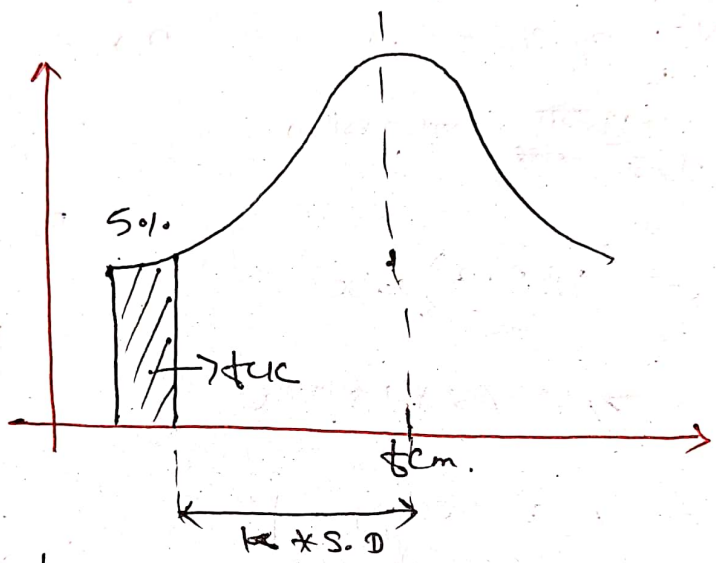
- → Required strength
- → Required durability
- → Required workability
- → Economical

} objective of mix design.

M20 → f_{ck} → characteristics compressive strength.

↓

mix design



→ f_{ck} is defined as compressive strength of concrete below which not more than 5% test results are expected to fall.

At 95% confidence level,

↓

M20 → Mix design

↓

100 cube test

↓

Compression strength ≥ 20MPa

As per IS guideline (IS 10262 guideline),

$f_{ck} = f_{cm} - K * S.D$, where f_{cm} = mean strength obtained from compression test.

K = probability factor

K = 1.65 [95% confidence factor]

S.D. = Standard deviation

* Minimum no of test sample of cube required to calculate actual Standard deviation (S.D.) is 30.

→ when test results of cube < 30,
Take assumed S.D. from code IS 456 : 2000

Grade of Concrete	Assumed S.D (σ) in MPA
i) M10, M15	3.5 N/mm²
ii) M20, M25	4 N/mm²
iii) M30, M35, M40	5 N/mm²

* M 20

at 28 days, 3 no. of cube test in lab

1st cube = 22 MPa
2nd cube = 23 MPa
3rd cube = 24 MPa

Mean strength (f_{cm}) = $\frac{22+23+24}{3}$ = 24 MPa.

$f_{ck} = f_{cm} - K * SD$

$= 23 - 1.65 * 4$

$= 16.4$ N/mm² < 20 mpa

(fail.)

→ mix design of concrete is always preferred because Probability concept is consider.

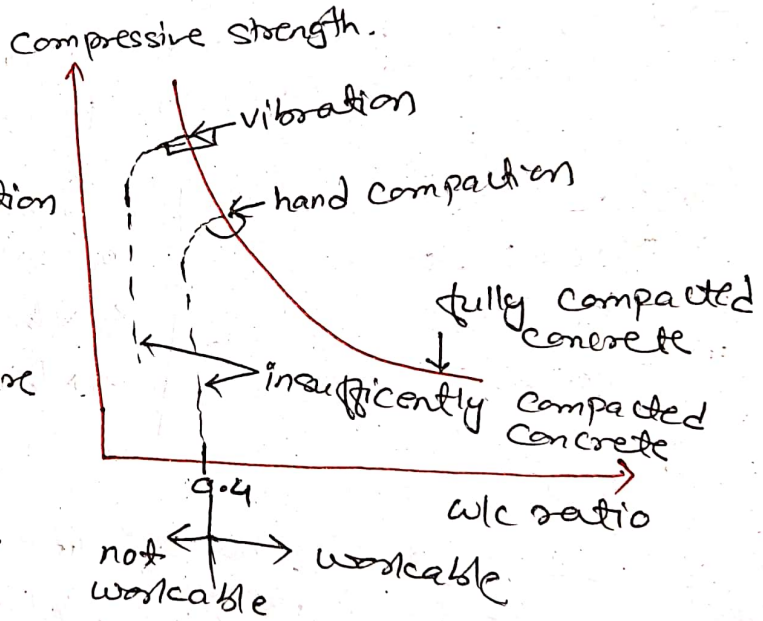
→ As far as possible, mix design of concrete is carried out

Factor Affecting Strength of Concrete

1) Water cement ratio (w/c)

→ Abrahm's w/c ratio law :-

It states that, "Strength of concrete is only depend upon w/c ratio, provide that concrete is in workable condition."



→ when w/c < 0.4,
- → not workable
- → Insufficient compaction
- → Air voids remains in the concrete
- ↓
- Honey combed structure
- ↓
- Strength of concrete drastically reduced.

→ Strength of concrete $\propto \frac{1}{w/c}$ ratio.

ie. Strength of concrete increases with decrease in w/c ratio.

→ Strength of concrete is $\propto$ C/w ratio.

Cement-water ratio.

CRRI Chart : Graph plotted between w/c ratio and strength of concrete.

Mix	w/c
M10	0.6 to 0.65 (max.)
M15	0.55 to 0.6 (max.)
M20	0.5 to 0.55 (max.)
M25	0.45 to 0.5 (max.)

↓ min.

→ further lower value of w/c ratio is not permissible i.e. (w/c < 0.45) so plasticizer is used for higher grade of concrete.

→ To prevent phenomenon of honeycombing, min w/c ratio is : 0.45

* for full hydration of cement, min. w/c ratio = 0.36.

Q. w/c ratio is measured in terms of :

a) $\frac{\text{volume of water}}{\text{volume of cement}}$

b) $\frac{\text{weight of water}}{\text{weight of cement}}$

c) $\frac{\text{volume of water}}{\text{weight of cement}}$

d) both (a) & (b)

Accurate method is always weight batching

Note:

⇒ Secret w/c ratio, takes in account the voids in concrete in estimating strength.

w/c ratio of cement depends on:

i) Degree of hydration of cement
ii) Temperature at which hydration takes place,
iii) formation of cracks due to Bleeding and shrinkage
iv) Air content in case of air entrained concrete
v) Change in w/c ratio.

2) Age of Concrete

→ with passage of time, strength of concrete increases

Age of Concrete	3 days	7 days	21 days	28 days	3 month	6 mth	1 year
Strength gain of concrete	0.4	0.65	0.9	1	1.15	1.2	1.25 to 1.3

↓ full strength

Earlier strength development ← → ultimate strength

↓ Rate of strength development is high.

↓ low rate of strength development

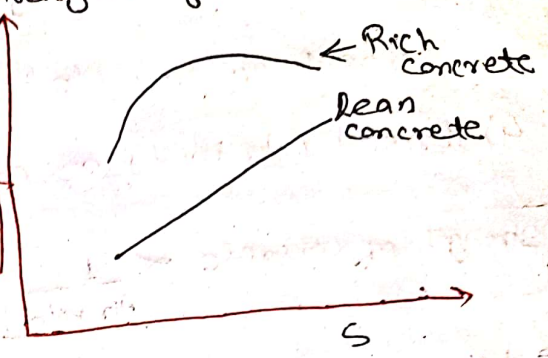
Q. As compared to 28 days, concrete strength / strength of concrete after 1 year will be:

a) 15 %. b) 20 %. c) 25 to 30 %. d) 50 to 60 %.

3) Shape and Size of aggregate

In lean concrete,
↳ Cement कम और
Aggregate ↗ sand की
Compare में e.g (M10)

Strength of concrete ∝ Size of aggregate.



In rich concrete,
↳ Cement की मात्रा,
→ Strength is increased upto certain value, after that is decrease.

* In general, **Strength of concrete ∝ size of aggregate**
(Nominal max. size of aggregate)

Strength for different shape of aggregate

i) Rounded shape aggregate :→ Strength of concrete is decrease, as no interlocking between aggregate

ii) Crushed angular aggregate :→ strength of concrete is increased due to interlocking (bonding better compacted)

iii) flaky shape aggregate :→
for flaky aggregate,
least dimension (thickness) of aggregate $\leq \frac{3}{5}$ th of its mean dimension of aggregate.
$(3/5 = 0.6)$

Note:
20mm down
10mm retained
} aggregate (← thickness) $\leq 0.6 * 15$

mean dimension $= \frac{20+10}{2}$
$= 15$

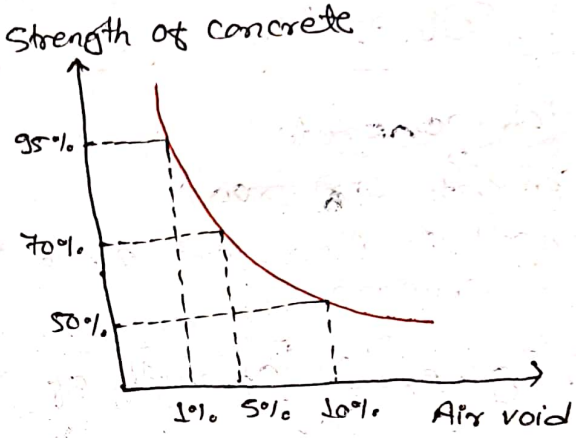
* **Strength of concrete decrease in flaky shape**

iv) Elongated shape aggregate :
largest dimension (length) of aggregate $\geq \frac{9}{5}^{th} = 1.8$ of its mean dimension.

→ Strength of concrete is decreased.

4) Porosity (Air void) of concrete

Strength of concrete $\propto \frac{1}{\text{Air void}}$



→ 1% air void in concrete, strength of concrete is decreased by 5%

→ 5% air void → decreased by 30%

→ 10% air void → decreased by 50%

So, fully compaction should be required for better strength.

5) Temperature of concrete

Strength of concrete $\propto \frac{1}{\text{temperature of concrete}}$

→ Concreting work is to be stop when ambients temperature fall below 4.5°C.

6) Maturity of Concrete

Strength development of concrete depends upon time and temperature of concrete.

Maturity of concrete is :

$= \Sigma(\text{time} * \text{temperature}) = (^{\circ}C * \text{hours})$

↓ unit.

→ Datum temperature for maturity of concrete is −11°C (Bowman datum temperature).

→ upto −11°C, hydration of cement is continue.

7) Gel-space ratio

→ defined as volume of hydrated cement paste to the sum of volume of hydrated cement and that of capillary pores.

Acc. to power law,

Theoritical strength = $240 X^3$ N/mm²

where, X = Gel space ratio = $\frac{0.657C}{0.329C + Ww}$

C = wt. of cement

Ww = wt. of water.

Note:

1) 1ml of cement on hydration produces 2.06ml of gel.

2) Limitation: Theoritical strength >> Actual strength of Concrete.

3) Higher gel-space ratio, reduces the porosity, and hence increases the strength of concrete.

4) Higher w/c ratio decreases the gel-space ratio, increases porosity and thereby decreasing the strength of concrete.

Test of hardened concrete

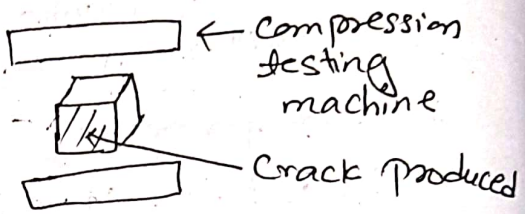
i) Destructive test (DT)
ii) Non-destructive test (NDT)

1) Destructive Test

→ Spoon

A) Compressive strength test

i) Cube Test



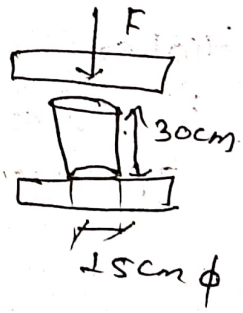
At 28 days,
failure load = F
Contact area = A
Size : 15 cm mould size
for max. nominal 40mm size of aggregate
: 10cm mould size
for max. nominal 20mm size of aggregate.
At least 3 cube tests are required.

→ Testing is done at interval of : 1, 3, 7, 14, 28, 90 & 365 days.

∴ Compressive strength of concrete = $\frac{\text{force at failure}}{\text{Area}}$.

ii) Cylinder test

mould size : 15cm ϕ, 30cm height.
F = failure load, $\frac{\text{height}}{\text{diameter}} = 2$.
A = Area
Compressive strength = F/A.



for same concrete min:
Cube strength = 1.25 * Cylindrical strength } Acc. to British standard.
Cylindrical strength = 0.8 * Cube strength.

Comparision between Cube and Cylinder Test:

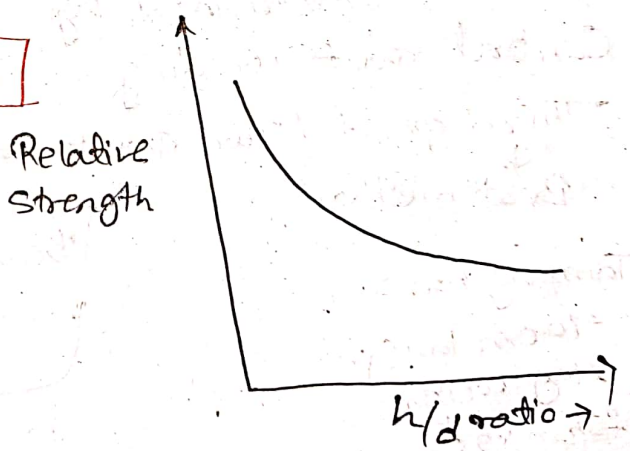
Cylinder Test	Cube Test
→ load distribution is more uniform as circular c/s.	→ load distribution is non uniform as square c/s.
→ No stress concentration ↓ Gives uniform realistic results	→ stress concentration ↓ Non uniform results
→ Capping restrain is less ie. less contact area.	→ Capping restrain is more ie. more contact area.
→ Adopted by ACI Code in research field	→ Adopted by IS, BS, NBC

Q. The compressive strength of 15cm cube in comparision with with 10 cm cube from same concrete mix will be:
a) more b) less c) equal d) All

Q. The compressive strength of 15*15cm cylinder in comparision with 15*30 cm cylinder from same concrete will be:
a) more b) less c) equal d) All

↓

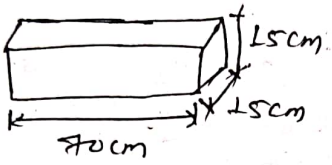
$\frac{h}{d}$ ratio ↑, Relative strength ↓

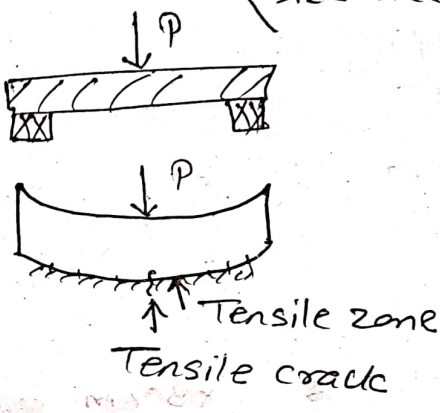


B) Flexural Tensile strength Test
(modulus of rupture)

→ Tensile strength of concrete is determined from indirect test.
(flexural tensile strength test)

→ for determining modulus of rupture of concrete (f_{cr}),
Specimen (mould) size: 15cm * 15cm * 70cm {for aggregate size under 38}





→ As per IS 456 : 2000,
modulus of rupture of concrete is:
$f_{cr} = 0.7 * \sqrt{f_{ck}}$

→ flexural tensile strength of concrete is measured by modulus of rupture (f_{cr}).

flexural tensile strength of concrete i.e. modulus of rupture is determined by
1) Central point loading
ii) Third point / Two point loading
↓
Best method

* Tamping bar:
40cm long,
2kg weigh
25mm x 25mm: tamping section

Beam mould: 10 x 10 x 50cm
for aggregate size under 19mm

Note:

$f_{cr} > f_{ct} > f_t$

where, f_{cr} = flexural tensile, $f_{cr} = 0.7 * \sqrt{f_{ck}}$

f_{ct} = split tensile strength $= 0.35 * \sqrt{f_{ck}}$

$= 0.67 * f_{cr}$

f_t = direct tensile from briquette test

$= (0.5 \text{ to } 0.625) * f_{cr}$.

Q. Tensile strength of concrete is measured by:

a) Direct tension test in the UTM,

b) Applying compressive load along the diameter of cylinder

c) Applying third point loading on a prism

d) Applying tensile load along the diameter of cylinder.

Q. Tensile strength is ____ the flexural strength.

a) $225 cm^2$ b) $2250 mm^2$ c) $0.225 m^2$ d) All of above

Q. In cylindrical specimen, failure plane makes an angle with the horizontal is:

a) 30° b) 45° c) 60° d) 75°

Q.

2) Non-Destructive Test (NDT)
→ Done if the structure is already build
→ Specimen is not destroyed,
→ Test of specimen as in existing condition,
→ Approximate method
→ used for strengthening of existing structure.
e.g. retrofitting purpose.

These are:

I) Re-bound Hammer test :- To determine the concrete compressive strength

II) X-Ray (ferro-scan) → To detect the steel reinforcement : its position, size, location, cover

III) Pulse velocity test : concrete compaction, defect

Freshly Mixed Concrete :

→ Green concrete or plastic concrete
↳ can be moulded into any desire shape

Properties :
1) workability
2) Segregation
3) Bleeding
4) Harshness

1) Workability of Concrete

→ Property of freshly mixed / prepared concrete which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished.
→ Higher the workability, greater is the ease for these processes
→ CRRI : Capital Road Research institute
* Amount of useful internal workdone necessary to produce fully compaction of concrete.

* CRRI charts are used to obtain relationship between strength of concrete and w/c ratio.

low w/c content ⇒ Difficulty in mixing, compaction of concrete
↓
Difficulty in mobility, lubricating
↓
Internal friction more for mixing
↓
more work done
↓
less workability

factors affecting workability of concrete :→

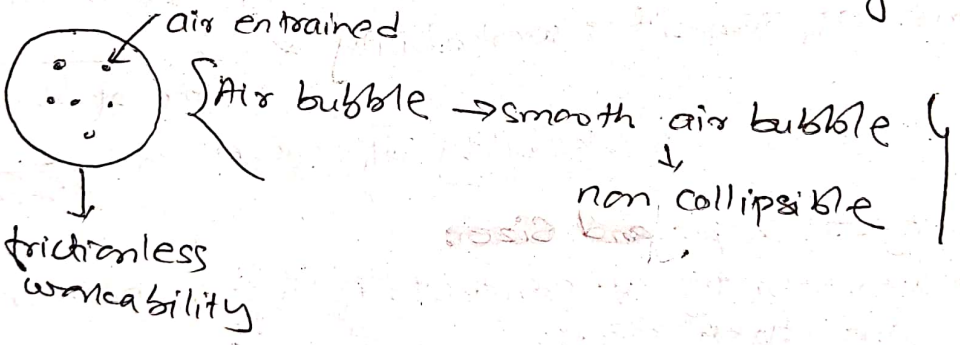
1) w/c ratio : workability of concrete ∝ w/c ratio
2) Types of concrete mix : workability ∝ cement content
3) Time of Transit : workability ∝ $\frac{1}{\text{Time of transit}}$
4) Temperature : workability of concrete ∝ $\frac{1}{\text{temperature}}$
5) Aggregate shape :
   → workability of concrete is less in angular, elongated and flaky shape.
   → workability of concrete is more in rounded shape.
6) Aggregate size :
   → workability of concrete ∝ Aggregate size
7) Aggregate cement ratio :
   workability of concrete ∝ $\frac{1}{\text{Aggregate cement ratio}}$
8) Surface texture of aggregate :
   Smooth and glossy aggregate : Higher workability
   Granular & porous aggregate : lower workability
9) Air entrainment :
   increases workability

1) Grading of aggregate

Well Graded	Gap Graded	Poorly Graded
↓	20mm retained (↑)	↓
All size of aggregate are mix proportionally	Gap	Certain size of aggregate is Pre dominant
↓	10mm pass (↓)	
minimum void	→ Certain size of Particle is missing	
↓	↓	
Uniform distribution	Non-uniform distribution	

ii) Admixtures

→ Plasticizers and super plasticizers (air entrained agent) increases workability
↓
lubricating



2) Seggregation

→ Properties of freshly mixed concrete in which seperation of ingredients of concrete ie. Coarse aggregate, fine aggregate and cement paste

→ Breaking up of cohesion [bonding] is called Seggregation.

Causes of Seggregation

1) Dropping of concrete [placing] from more than 1m,
   - To prevent from seggregation of concrete dropping height [placing height] should not be more than 1m.
   Acc. to IS 456:2000,
   * Permissible free fall height of concrete is 1.5.
2) Over vibration
3) more w/c ratio,
4) Bad proportioning

Effect of seggregation on concrete

→ Due to non-homogenous mass of concrete air voids are likely to entrapped in concrete.
→ Honey-combed concrete formation : Results into decrease in strength of concrete.
→ Harsh surface (non-uniform surface) of concrete

Measures :

→ Concrete should not be placed from more than 1m height when admixture is not used
→ Admixture is used to prevent from seggregation.

3) Bleeding of Concrete

→ Properties of green concrete in which water or cement paste tends to rise to top surface of concrete.

Causes

→ more w/c ratio → Bad mixing / proportioning
→ Over vibration

Effect

→ Honey combed concrete,

↓↓

Voids created in concrete mass

↓ Results

Strength of concrete reduced drastically.

→ Harsh surface of concrete

Measures

→ Appropriate w/c

→ Proper batching, mixing, transportation, placing, compaction of concrete.

4) Harshness of concrete surface

→ Properties of green concrete in which it is difficult to obtain smooth finishing of concrete surface is called harshness.

Causes

→ Segregation, bleeding

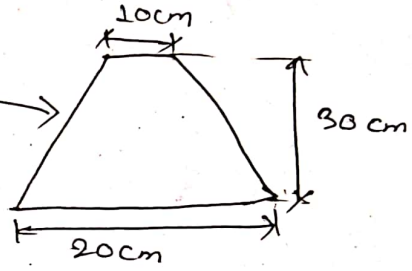
Measurement of Workability of Concrete
(Tests performed to degree of workability):

A) Slump Test

→ Commonly used test to determine consistency of concrete (consistency = determination of water cont in concrete)
→ Conducted in lab as well as in site
→ Suitable for medium to higher degree of workability
→ Only applicable for concrete having nominal maximum size of aggregate ~~not~~ 38mm

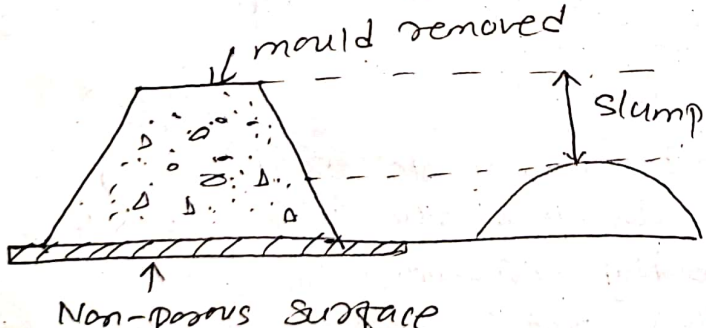
Apparatus Required

→ Metallic mould in form of frustum of cone.
→ Tamping rod (16mm ϕ, 0.6m height)
→ measuring tape (steel tape)



Process

→ Concrete is filled into 4 equal layers [each layer is of thickness 1/4th of height of mould]
→ Each layer of concrete is compacted with 25 Number of Stokes.



Slump value (mm) → decrease/reduction. Subsidence in height of concrete due to self weight of concrete after removal of mould.

Slump Patterns

1)

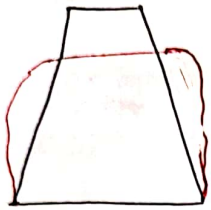


fig: True slump

← decrease in height uniformly
← only slump that can be measured in test
→ obtained when concrete mix is prepared with full consistency.

2)

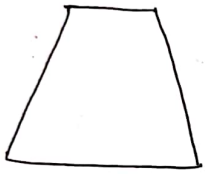


fig: zero slump

← indication of very low w/c ratio which results in dry mix.
← This type of concrete is generally used for road construction.

3)

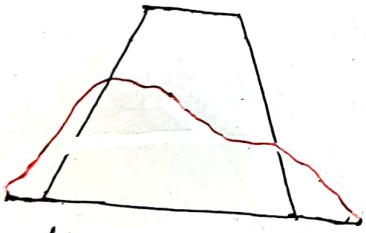


fig: Shear slump

→ indicates that the result is incomplete & concrete to be resisted.
→ indicates lacks of cohesion.
→ Not suitable for placement
→ unequal slump value due to bad mixing & batching.

4)

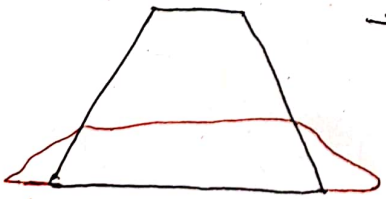


fig: Collapse slump

→ indication that w/c ratio is too high ie. concrete mix is too wet, mix is lean.
→ has high workability mix, for which a slump test is not appropriate
→

Degree of workability of concrete	Slump value.
1) Very low : vee-bee time test e.g. Dry concrete: w/c very low	0-25mm.
2) low : Compacting factor test (semi-plastic concrete)	25-50mm
3) Medium ← slump test → use: for concreting works (Plastic concrete)	50-100mm
4) High	100-150mm
5) very High : flow table test (wet concrete)	150-200mm.
fluid concrete → > 200 mm slump value	

Types of concreting works	Slump value, without use of Admixture
1) Mass concreting	25-50mm
2) Rigid Pavements	20-30mm
3) RCC beams, slab, footing	50-100mm
4) RCC Columns, shear walls and Retaining walls	100-150mm

Q.1) Slump test of concrete is used to determine :
a) mobility of concrete
b) Homogenity of concrete
c) Consistency of concrete
d) All of the above

Q.2) A concrete having slump value of 6.5 cm is said to be:
a) Dry concrete
b) Semi-plastic concrete
c) Plastic concrete
d) fluid concrete

Q.3) Higher degree of workability of concrete is required, if structure is :
a) Thin & lightly reinforced
b) Thick & lightly reinforced
c) Thin and heavily reinforced
d) Thick and heavily reinforced (for large surface)

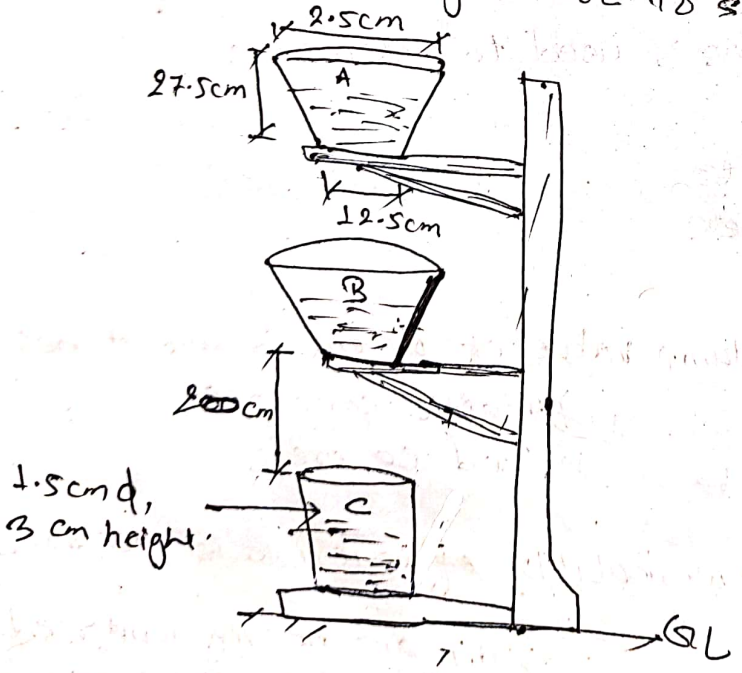
B) Compaction factor Test

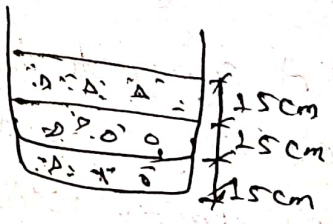
→ done for low degree of workability,
→ only conducted in lab,
→ Developed by CRRI [Central road research institute]
→ accurate and reliable method.

Hand compaction	Machine compaction (vibration)
↓	↓
High degree of workability	low degree of workability
↓	↓
slump value high	slump value is low
(50–100)mm generally	(25–50)mm generally

Working Principle:

→ Degree of compaction is measured in terms of amount of useful internal workdone when concrete is placing- from certain height due to self weight of concrete.





→ Degree of compaction called the compacting factor & is measured by density ratio.

Compacting factor (C.F) = $\frac{\text{wt. of partially compacted concrete}}{\text{wt. of fully compacted concrete}}$

Compacting factor = (0.78 – 1)

= 1 for fully compacted.

c) Vee-Bee Test

→ used for very low degree of workability of concrete (insufficient compaction)

→ used for dry concrete (w/c ratio is very low)

→ fully hydration of cement is difficult.
for full hydration, we use admixture.

d) Flow-Table Test

→ used for very high degree of workability

→ used for wet concrete (w/c ratio is very high)

→ Strength of concrete is drastically reduced.

Operation of manufactured of hardend concrete

1) Batching

→ Process of accurate measurement and proper proportioning of concrete materials are called batching.

→ Required strength, Required workability, Required durability and economical

Methods:
i) Volumetric batching
ii) weight batching

I) Volumetric Batching

→ used in minor concreting works
→ Bulking error may occurs
→ Not accurate method.
→ designed only for Nominal mixing.

1 Bag of cement, mass (m) = 50 kg
density (ρ) = 1440 kg/m³

Volume of 1 bag (V) = $\frac{m}{\rho} = \frac{50}{1440} = 0.0347 m^3$

$\approx 0.035\ m^3$

⇒ 1 bag of cement = 35 litre

Batching box capacity = 1 bag cement = 0.035 m³

for M20 mix (1:1.5:3), Nominal mix is:

Cement	Sand	Aggregate
→ 0.035 m³	0.035 * 1.5	0.035 * 3 m³
= 35 L	35 * 1.5	35 * 3
	= ___ Lit	= ___ Lit

w/c = (0.5 - 0.55)

If w/c = 0.52, water req. = 0.52 * 35 = ___ Lit.

II) Weight Batching : Mix design
→ Accurate method : Batching plant
→ Errorless
→ used for important types of concreting works

2) Mixing :
→ Dry mixing of cement sand and aggregate.
→ wet mixing : throughly; uniform colour & homogenous

Types of mixing :

i) Manual Mixing (Hand mixing)
→ w/c ratio is more
→ Small concreting works
→ 10 % more cement is added.
→ not through homogenous

ii) Machine Mixing
→ w/c ratio is less
→ Major and large concreting works
→ Economical, accurate method.
→ Homogenous.

* Number of revolutions of drum [Concrete mixing] should be [15 to 20] rpm (speed) for wet mix.
* Time period for wet mixing : 2–3 min
[No. of rotation = 60]

3) Transportation
* Means of transportation of concrete
↓
ⓐ iron pans ⓑ wheel barrows ⓒ Pumps ⓓ Trucks ⓔ Conveyors
ⓕ chute [Underground slope] ⓖ Crane buckets.

4) Placing
→ Process of putting the concrete in desired place
· Precautions :
* Concrete should not be thrown from height more than 1m,
* Placing is optimum at 27 ± 2°C & shall not be done in very cold surface.

Note: 1) for Pumping of concrete:
i) Pipe diameter should not be < 300 mm
ii) w/c = 0.5 to 0.6
iii) Slump value = 60-80 mm
iv) Max. Horizontal distance upto 400m.
v) Max. vertical distance upto 50m.
vi) No. of bends of pipe should be minimum.

2) The layer of concrete should not exceed 15 to 30cm.

3) Process of mixing, transportation, placing and compacting the cement concrete should not take more than 30 minutes.

5) Compaction of concrete

Why? → To eliminate air void from concrete volume
→ To increase density of concrete (to make it dense)
→ To increase durability (to reduces permeability of concrete).

→ With passage of time, permeability of concrete will decrease.

* Methods of compacting concrete

i) Needle vibration or Internal vibration or Poker or Immession vibrator

→ Commonly used method for compaction of large section of mass concrete ie. for RCC dams, beams, column. > 20cm.
→ frequency of vibration of needle is nearly upto 12000 cycle per minute.

ii) form work Vibration or external vibration

→ Recommended to use in thin vertical concrete member (thin column, thin shear wall)
→ Gives better (smooth) finishing
→ {for one way or PCC}

iii) Table vibrator
→ used in lab for compaction of cube, cylinder etc.

iv) Platform Vibrator
→ Similar to table vibrator but large in size.
→ used to compact pre-cast concrete member
[factory made product]

v) Surface vibrator or Screed vibrator
→ used for levelling and compaction of thin horizontal concrete member like roof slab, floor slab, concrete pavement,
→ only applicable for concrete horizontal member with thickness ≤ 15cm. [can be used upto 25cm].

vi) Roller vibrator
→ used for compaction of mass concreting like dam, large ~~mat~~ size mat foundation.

vii) Compaction by spinning (Rotation)
→ for production of circular concrete section like hume pipes [centrifugal forces],
↳ Compaction.

Note:
for machine compaction → {w/c less, strength high}, slump value of concrete < 50mm,
for hand compaction, slump value of concrete → (50 - 100)mm
↳ {w/c more, strength less}

Generally,
1% air void reduces concrete strength by 5%,
5% air void reduces concrete strength by 30%.
10% air void reduces concrete strength by 50%.

6) finishing of concrete

→ Process of forming dense concrete with smooth and plain surface

→ Best finishing is obtained when slump value is

Stages of finishing:

a) Screeding: Process of removal of humps and hollows and give a true and uniform surface

b) floating: → Process of removing of irregularities left from screeding.

→ Done by using wooden float of 1.5m long and 20cm wide. (l/b = 7.5)

c) Trowelling: final stage, produces a smooth and dense surface.

7) Curing of Concrete

→ Process of wetting the concrete with water so as to make it able to gain strength sufficiently is called curing

→ Concrete gains strength upto 100% after curing of 28 days.

→ water containing more than 0.08ppm of iron is not recommended for curing

→ Curing compound used are: bitumen, Sodium Silicate linseed soil, wax & Chlorinated rubber.

It is done:

→ for promotion of hydration of cement

→ To eliminate shrinkage crack

→ To preserve the properties of concrete.

Results of curing: i) Strength enhancement

ii) Increase in durability.

Methods of Curing :

a) Moist Curing

→ Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding.

i) In case of OPC : 7 days (min)

ii) If mineral admixture & blended cements are used then 10 days (min.) (can be extended upto 14 days)

iii) 10 days for dry and wet weather condition.

b) Membrane Curing

→ Impermeable membranes such as polyethylene sheeting coverings closely the concrete surface are used to prevent evaporation.

→ Concrete may not achieve full hydration as in moist curing.

c) Steam Curing

→ Also called accelerated curing

→ Have advantages in producing Precast concrete product

→ Concrete member is heated by steam at 95°C either at high or low pressure

→ At low pressure, steam curing about 70% of the 28 days compressive strength can be obtained in 16–24 days.

→ High pressure steam curing can be applied to precast concrete member and give 28 days compressive strength in 24 hours but reduce bond strength by 50%.

→ low w/c respond more favorably to steam curing than those with higher w/c.
→ steam curing increased sulphate action and to freezing and thawing.

d) Chemical curing
→ Liquid membrane forming curing compound such as Sodium Silicate solution are used.
→ They form a film, fill the pores, seal the surface voids and prevent evaporation.
→ Application should be made immediately after the concreting has been finished.

e) Electrical curing
→ Curing by passing alternating current of low voltage and high current through electrode.
→ Evaporation is prevented by using an impermeable rubber member on the top surface of concrete
→ Concrete can attain the normal 28 days strength in a period of 3 days.
→ Expensive Technique.

Note:
i) Min. 14 days curing for RCC structure
ii) for horizontal concrete member ie. roof slab, flat slab and rigid pavement. Ponding method (moist curing) is used.
iii) for vertical concrete member, Spraying of water with jute bag covering straw.
iv) for curing cube, cylinder in lab, immersion in curing tank.

Q. No shrinkage occurs when relative humidity is :
a) 50 % b) 80 % c) 90 % d) 100 %

Admixture

→ Compounds which when added to concrete enhances properties like strength, hardness, durability etc.

functions:
→ To accelerate the setting and hardening of concrete
→ To retards the setting and hardening of concrete
→ To prevent the segregation and bleeding
→ To make water proof concrete.
→ To increase workability and durability.

Types of admixture

A) Accelerator

→ for early strength development
→ for emergency repair work of concrete
→ for under water concrete

Use: early removal of formwork, Early used of concrete

function: → decrease the setting time of concrete.
→ increases rate of hydration of hydraulic cement
→ accelerates the action of C_3S and C_2S.
→ increases the rate of hardening or strength development.

Commonly used accelerating admixtures are:
i) Triethenolamine,
ii) Calcium formate
iii) Silica fume
iv) Calcium chloride → Commonly used → max. dosage : 2% of weight of concrete.
v) Finely divided Silica gel

Use:
for construction in low temperature regions,

B) Retarders

→ To prolong the setting and hardening of concrete by suspending the action of C_3A and C_3S.

→ used for large and continuous batching of concrete to prevent the formation of cold joints.

→ used in :→ Hot weather, rainy weather
→ Sufficient time period for compaction, finishing
→ high workability.

Commonly used Retarders:

i) Gypsum [$CaSO_4 \cdot H_2O$]
↓
Dosage → (3-4)% of wt. of concrete

ii) Common sugar acts as retarder
↓
0.5% of wt. of cement sugar

iii) Glucose
iv) Starch
v) Cellulose etc.

C) Plasticizers and Super plasticizers

→ water reducing admixture

→ To achieve a higher strength by decreasing w/c ratio at the same workability as an admixture free mix.

→ Plasticizers acts as lubricating agents when added.

Functions of Plasticizers

→ Reduce head of hydration in mass concrete
→ Increase workability, durability
→ Reduce water content for given workability upto 15%
→ Decrease surface tension of water
→ Plasticity of concrete increase
→ Retards the setting time

e.g. Ligno-Sulphate, Hydro carbolic acid

Super plasticizers

→ more effective
→ increase fluidity of concrete
→ Gives very high early strength → 200 % at 24 hrs.
→ Gives very high later strength → 100 MPa.
→ water reduction upto 30 %
→ Dosage : low (0.6 to 2%) on cement.

Eg: SMF, PCE, SNF etc.

d) Air-entraining agent

→ Introduction of small ball bearing particle like air bubble into mass of concrete.

⇓

Air bubble → lubricating agent [friction decrease]

↓

- increases workability
- eliminates the chances of post action.
- Reduces bleeding, laitance, segregation, porosity etc.

e.g * Aluminium powder.
+ Commercial products like ~~re~~ vinsol resin, darex, Teepol, cheecol etc.
* Natural wood resins, alkali salts, fats & oils etc.

Entrained Air	→ Entrapped air
→ Artifical introduction of air bubble [Non-collapsible of small ball bearing particle]	→ Naturally occuring air void in concrete
→ Strength doesnot change.	→ Strength of concrete is reduced
→ workability is increased.	→ workability is reduced.
→ Desirable	→ undesirable ↓ Removed by compaction.
→ Bleeding & segregation is reduced.	

Stripping of form:

→ Concrete is support by framework, till it gains sufficient strength, after this formwork can be removed.

* Minimum stripping time (Removal time of formwork & props) such that, when:

Strength gain by concrete > 2* stress at which concrete is subjected.

↓↓

self weight, live load

Types of structural components	Stripping time period
1) Vertical RCC member (Column, shear wall, retaining wall)	16-24 hours
2) Soffit formwork to slab. (Props are refixed immediately after removal of formwork)	3 days
3) Soffit (bottom) formwork of beam	7 days.
4) Props of slab:	
i) Spanning upto 4.5m	7 days
ii) Spanning over 4.5m	14 days
5) Props to beams and arches	
i) Spanning upto 6m	14 days
ii) Spanning over 6m	21 days

for other condition, modification should be required.

Defects of Concreting:

i) Bleeding : appearance of water on surface
ii) Segregation : Seperation of particle from concrete
iii) Laitance : watery scum on surface
iv) Honey combing : Rough surface that contains voids in the concrete as a result of incomplete filling of the concrete against the formwork.

Poisson's Ratio

→ Poisson's ratio of concrete under static loads is lower than that of concrete upon which dynamic loads are applied.

→ Concrete Poisson's ratio under dynamic loads varies mostly between 0.2 to 0.25.

→ Ranges from 0.1 for high strength concrete to 0.2 for low strength concrete.

→ for concrete structure design, Poisson's ratio = 0.2

→ Poisson's ratio of concrete decreases with richer mixes

Types of Concrete

A) Based on Density

1) Light weight concrete
   - → sp. weight : 3 kN/m³ to 12 kN/m³
   - → Made by adding light wt. aggregates like pumice (obtained from volcanic source).

2) Normal weight concrete
   - → Sp. wt = 23 to 26 kN/m³
   - → Made by adding granite, basalt, trap, quartz etc.

3) Heavy weight concrete
   - → Specific weight : 28 to 29 kN/m³
   - → Made by adding heavy wt. aggregate like iron scrap, blast furnance slag etc.

B) Based on Design

1) Plain cement concrete (PCC) : (24 kN/m³)
   - → Made from the basic components of concrete [Binding material, water & aggregate]
   - → Strong in taking compressive strength.

2) Reinforced cement concrete (RCC) (25 kN/m³)
   - → Made by adding reinforcement [usually in tensile zone] to increase the strength of concrete.
   - → Strong in taking tensile, compressive & shear strength.

3) Pre-stressed concrete
   - → Initial compression is induced in concrete so that it can resist tension with greater efficiency.

4) Special Concrete

i) Polymer Concrete composite

→ Polymers are used as binder instead of lime/cement.
→ used for repairing of old concrete as the adhesive properties of polymer concrete allow repair to be more effective.

ii) fiber reinforced concrete (FRC)

→ Concrete containing fibrous material which increases its structural integrity.
→ Contains short discrete fibres that are uniformly distributed and randomly oriented.
→ fibres included steel fibres, glass fibres, synthetic fibres and natural fibre.

Advantages of FRC:

→ Improves structural strength,
→ Reduce steel reinforcement requirements,
→ Reduces crack widths and control widths tightly, thus improving durability.
→ Improve impact and abrasion resistance.

* used as replacement to conventional type RCC and PCC in modern countries but not yet started in Nepal

iii) ferrocement Concrete

→ Contains a system of reinforced concrete reinforced by adding a thin layer of metal mesh, woven expanded-metal or metal-fibers and closely spaced thin steel rods such as rebar.

→ used to construct relatively thin, hard, strong surfaces & structures in many shapes.
Such as: hulls for boats, shell roofs, combustion tanks, water tanks.

iv) Saw-dust concrete [Powdery particle of wood]

→ used as a partial replacement for fine aggregates in concrete production.

→ Increase in % of saw dust instead of sand in concrete led to crossponding reduction in compressive strength.

→ Optimum saw dust content is about 10% and its crossponding compressive strength at 28 days is 7.41 N/mm².

→ This concrete cannot be used for structural application and is generally used for panal walls, sound proofing, head and sound proofing etc.

* Saw-dust can be rendered chemically inert by boiling it in water containing ferrous sulphate.

v) Air-entrained / cellular or aerated concrete

→ Contains billions of microscopic air cells per cubic foot.
→ Air entrainment increases workability,
→ used in head and sound insulation,
→ Has strength less than 10% to 15%
→ light in weight
→ w/c ratio is reduced & proportion of aggregate is reduced,

* Vaccum Concrete

→ Cement concrete from which entrained air and excess air after placing is removed with a vaccum pump after placing it in position.
→ Removal helps in increase in strength by 15 to 20%
→ Can be used in all reinforced concrete works.

* Light weight concrete
→ Prepared by using coke breeze, cinder or slag as aggregate
→ Posses high insulating property
→ used for making precast structural units for partition and wall lining purpose.

* Bacteria Concrete
→ Also called calcium carbonate concrete
→ Has ability to seal, heal the crack

* Pre-packed concrete
→ A concrete in which dry coarse aggregate are packed to have the least voids and then the cement sand motar is injected under pressure to fill all voids resulting in very dense concrete.

Aggregates:

→ Major ingredient of concrete
→ Chemically inert, inexpensive material distributed throughout concrete so as to produce large volume.
→ Acts as an economical filler
→ Provides Rigidity, stability, durability and strength to concrete.

Types of Concrete

A. Based on source (Geological classification)

1. Natural Aggregate
   → Aggregate derived from river bed, quarry etc..
   * Aggregate from igneous rocks: Hard, tough, dense in nature e.g. Basalt, Granite.
   * Aggregate from sedimentary rocks: of varying quality eg. Sandstone
   * Aggregate from metamorphic rock: e.g Gneiss, Quartzite

Note: To obtain a very high strength concrete, use very fine grained granite.

2) Artifical Aggregate
   → Created artifically.
   → Broken bricks, blast furnance slag and Synthetic aggregates are artifically created aggregates

Brocken bricks: Known as bricle bats,
   → Suitable for mass concreting e.g. foundation bases
   → Not suitable in reinforced concrete works

Synthetic aggregate: Produced by thermally processed materials such as expanded clay & shale
   → used for making light weight concrete.

Blast furnance slag aggregate
→ obtained from slow cooling of slag followed by crushing.
→ Has good fire resisting characteristics
→ Responsible for corrosion of reinforcement due to sulphur content.
→ Sp. Gravity range : 2 to 2.8
→ used to make precast concrete products.

B) Based on Size

i) Coarse aggregate : larger than 4.75mm and smaller than 75mm IS sieve.

* 75mm size aggregate is called Cyclopeon.

→ Size is governed by thickness of section, spacing, clear cover mixing etc.
→ for economy, max. size should be as large as possible but not more than 1/4th of minimum thickness of member.
→ for reinforced section, max. size should be at least 5mm less than clear spacing and also at least 5mm less than clear cover.
→ Aggregate more than 20mm size seldom used in RCC structural member.

ii) fine aggregate : larger than 75 micron and smaller than 4.75mm IS sieve

iii) Graded aggregate : Aggregate most of which passes through a particular size of sieve.

Note:
i) Coarse aggregate : 75mm - 4.75mm
ii) fine aggregate : 4.75mm - 75μ
iii) Silt : 0.06 - 0.002 mm
iv) Clay < 0.002mm

Zone-I : coarse aggregate Requires high w/c ratio
Zone-IV : finest aggregate.

All in aggregate : Naturally available aggregates of different fractions of fine and coarse size.

C. Based on Shape

1) Rounded aggregate :
- → generally obtained from river and sea shore
- → Has minimum % of voids 32-33 % and surface area to volume & cement paste required is minimum.
- → Has less bond stress and not suitable for pavement subject to tension.
- → Not suitable for high strength concrete. (due to poor interlocking bond)

2) Irregular Aggregate
- → Partly formed by attrition e.g. Pit sand, shore gravel
- → Posses 35 to 38 % voids.
- → Provides low workability and average interlocking.
- → Not suitable for high strength concrete
- → Maximum water required
- → Suitable for making ordinary concrete.

Q. The type of aggregate not suitable for high strength concrete and for pavement subjected to tension is : Round aggregate.

3) Flaky aggregate :
Smallest / least dimension < 3/5 (0.6) of its mean dimension.

4) Largest dimension
largest dimension > 1.8 of its mean dimension.

Q If the particle passes through 25mm sieve and retained on 20mm sieve, find

i) Mean size of particle = $\frac{20+25}{2} = 22.5$

ii) flaky particle = $22.5 * 0.6 = 13.5$

iii) Elongated particle = $22.5 * 1.8 = 40.5$mm

5) Angular Aggregate

→ Posses sharp edge with angles

→ Posses maximum % of voids (38 to 45 %)

→ Requirement of cement paste is relatively more.

→ Because of best interlocking property, it can be used for high strength concrete.

D) Based on surface Texture

i) Smooth aggregate : Surface smooth and uniformly colored, eg. marble, shale etc. ↳ w/c ratio = 0.54

ii) Glossy aggregate : Having glossy patches, eg. seashell, black flint

Note : Not preferred for use in concrete

iii) Granular aggregate : Surface showing granular structure eg. Sandstone ↳ w/c ratio = 0.6

iv) Crystalline aggregate : Surface showing crystals eg. Granite

v) Honey combed aggregate : Surface showing lumpy cavities,

vi) Porous aggregate : surface is made of numerous small pores

E. Based on surface moisture.

1. Very very dry aggregate: No moisture is present in surfaces or pores.
2. Dry aggregate (air dry aggregate): Some moisture is present but surface is completely dry.
3) Saturated and surface dry aggregate: All pores are filled with moisture but there is no moisture in surface
4) wet or moist aggregate
→ Moisture is present in voids as well as in surface

* When the same aggregate is oven dried and all of its moisture vanishes then it is said to be bone dry aggregate.

F. Based on unit weight.

I) Normal weight
II) Heavy weight
III) Light weight

Aggregate	Sp. Gr.	Unit wt. (kN/m3)	Bulk density (kg/m3)	Examples
Normal	2.5-2.7	23-26	1520-1680	Sand, gravel, granite, Sand stone, lime stone
Heavy	2.8-2.9	25-29	> 2080	Scrap iron, Magnetite
Light	-	< 12	< 1120	Dolomite, Pumice, Cinder, clay

for construction of cement concrete,

Maximum size of aggregate	used for
40mm	← masonary work like dam, retaining walls etc.
20mm	← for reinforced member
10mm	← for floors

Properties of Aggregate

A. Physical Properties

1) **Grading** : → Process of determining the % by mass occupied by various size of aggregate is called grading.
   → done by siere analysis
   → Omission of certain grade of aggregate is shown by horizontal line in grading curve.
   → Omission increases workability and increases liability of segregation.

Q. If a grading curve is a horizontal between the portion of 20mm I.S siere and 4.75mm siere, then graded aggregate do not contain:
a) 20mm b) 10mm c) 4.75mm d) All of above ✓

Q. Grading of concrete in a concrete mix is necessary to achieve:
a) Adequate workability b) Higher density
c) Reduction of voids ✓ d) Better durability

Q. Grading should be continuous for
a) lean mix ✓ b) Controlled mix c) Rich mix d) None

2) **Fineness Modulus**
   → Numerical index to measure average particle size of aggregate.
   → F.M of aggregate = $\frac{\text{Summation of cumulative \% of weight retained on I.S siere}}{100}$
   → Higher the F.M, higher will be coarser particle.

* fineness modulus could be used to indicate the fineness of sand.

The following limits may be taken as Guidance.

a) F.M of fine sand = 2.2 – 2.6
b) F.M of medium sand = 2.6 – 2.9
c) F.M of coarse sand = 2.9 – 3.2
d) Coarse aggregate = 5.5 – 8.0
e) All in aggregate = 3.5 – 7.5

* It may be noted that fineness modulus of sand should not be less than 2.5 and not more than 3.

Q. The % of fine aggregate of FM 2.6 to be combined with coarse aggregate of FM 6.8 to obtain the aggregate of FM 5.4 in :

a) 30% b) 40% c) 50% d) 60%.

Here,

$$X = \frac{F_2 - F}{F - F_1} * 100$$

$F_1 \rightarrow$ FM of fine aggregate
$F_2 \rightarrow$ FM of coarse aggregate.
$F \rightarrow$ FM acc. to specified grading

$$= \frac{6.8 - 5.4}{5.4 - 2.6} * 100\ \%$$

$$= 50\ \%$$

⇒ Higher the FM, harsher the mix
Lower the FM, uneconomical mix.

3) Specific gravity

Apparent sp. gravity : defined as the wt. of oven dry aggregate divided by its absolute volume, excluding the natural Pores in the aggregate particles.

Bulk sp. Gravity : defined as the wt. of oven dry aggregate divided by its absolute volume, including the natural Pores in the aggregate particles.

Bulk density : defined as mass requiring filling a container of unit volume.
→ Expressed in kg/liter.
depends on : Shape, size, sp. gravity, grading of the aggregate and moisture content.
Density of natural aggregate : 2.6 to 2.7 or, 2.4 to 2.8

Q. Density of concrete
a) increase with decrease in size of aggregate
b) Is independent of size of aggregate
c) Increase with increase in size of concrete
d) All of above.

B. Mechanical Properties
i) Strength
→ It is resistance to compressive loads and is measured by aggregate crushing value test.

→ aggregate sample should be sieved through 12.5mm Siere
→ Then the sample retained in 10mm sieve should be collected
→ The oven should dry the collected aggregate sample upto 4hrs at 100°C to 110°C. Allow the sample to cool at room temperature.
→ The aggregate is placed in a cylinderical mould and load of 40 tonnes is applied gradually through plunger
→ The material crushed to finer than 2.36mm is seperated and expressed as a % of a original wt. taken in the mould. This % is referred as aggregate crushing value.

Tempering rod : 16mm ϕ, 45 to 60cm length.

→ The crushing value of aggregate is restricted to 30% for concrete used for roads & pavements & 45% may be permitted for other structures.

2) Hardness
→ Resistance to wear and tear
→ Measured by Los Angeles Abrasion (LAA) value test

3) Toughness
→ Resistance to impact and is measured by Aggregate Impact value test.

4) Bulking of Sand
→ When water is added to dry sand, it forms a thin film around the particles which causes them to seperate and volume increases.

→ fine sand > Medium sand > Coarse Sand
Bulking in different sands

→ Max. bulking is at water content of 4%.
→ for 10% moisture content by weight, bulking of sand increases by 50%.

Relation between bulking and moisture content of Sand :

Moisture content	% Bulking
2	15
3	20
4	25-30
5	22

Q. The proportion of ingredients in concrete mix are given by 1:2:4. what will be the actual quantity of sand per unit volume of cement, if it under goes 20% of bulking.

a) 1.5 b) 2.4 c) 4.6 d) 6.5

$\Rightarrow 1.2 * 2 = 2.4$

1.2 → proportion of sand

20% bulking

Q. If the depth of moist sand in a cylinder is 15cm and the depth of sand when fully inundated with water is 12cm, the bulking of sand is

a) 10% b) 12% c) 20% d) 25%

$$\text{bulking of sand} = \frac{h_1 - h_2}{h_2} * 100\% = \frac{15-12}{12} * 100\% = 25\%$$

h_1 = height of wetted sand

h_2 = height of fully saturated sand.

2) Bulking of coarse aggregate is

a) less as compared to sand

b) more as compared to sand

c) 15% at 4% moisture content

d) Negligible ✓

3) The max. bulking of sand is likely to occur at a moisture content of:

a) 5% (4% actually) b) 10% c) 15% d) 20%

c. Chemical Properties

1) Purity

→ Aggregate shall be free from organic matter, dust, chlorides and other chemical impurities.

Q. The sum of % of all deleterious materials in aggregate shall not exceed
a) 5 % b) 10 % c) 15 % d) 20 %.

Q. Sand generally contain salt if obtained from
a) Nala bed b) River beds c) Sea bed d) All of above

Q. The presence of salt in sand results in
a) Corosion in reinforcement
b) Scaling
c) Pitting
d) All of above

2) Water

water is required for
i) washing of ingredients
ii) Hydration of cement
iii) Mixing the ingredients
iv) Curing of concrete.

Requirement of water

i) The silt content should be less than 2000 ppm. It affect setting and hardening of concrete.
ii) organic content shall be less than 500ppm,
iv) Inorganic content shall be less than 3000ppm.
iv) water may be unsuitable as mixing water when the water has a high concentration of sodium or potassium because of high risk of alkali-aggregate reaction.

→ As a rule, any water with a PH of 6.0 to 8.0 ie. which doesnot taste saline or brakish is suitable for use.

→ water should be free from wild acids, alkalies and organic matter.

→ Alkali carbonates and bicarbonates in water should not exceed 1000 ppm.

→ Sea water increases the risk of corrosion in reinforcement.

Note:

→ water having sugar retards the setting time of concrete. 0.05% suger by wt. can retard the setting time by 4 hours.

→ Sea water reduces 28 days strength by 10-15%.

→ If 30% excess water is added, the strength of concrete reduces by 50% and 10% excess water reduces strength by 15%.

→ water used for ordinary concrete is equal to 5% by wt. of aggregate + 30% by wt. of aggregate.

→ Mineral oil greater than 2% by wt. of concrete reduce the concrete strength by more than 20%.

* Insufficient quantity of water:
  → Makes the concrete mix harsh
  → Makes the concrete mix unworkable

* Excess quantity of water
  → causes segregation in concrete
  → Causes bleeding in concrete.

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for proportioning of concrete by Arbitary method

$$w/c * P = 0.3P + 0.1y + 0.01z$$

- w/c : water cement ratio (water required)
- P : Quantity of cement by weight
- y : Quantity of fine aggregate by weight
- z : Quantity of coarse aggregate by weight.

Q. If 50 kg of fine aggregate and 100 kg of coarse aggregate are mixed in a concrete whose's w/c is 0.6. The wt. of water required for harsh mix is:

⇒ we have,

$$w/c * P = 0.3 * P + 0.1y + 0.01z$$

$$0.6 * P = 0.3 * P + 0.1 * 50 + 0.01 * 100$$

$$0.3 * P = 5 + 1$$

$$P = 6/0.3 = 60/3 = 20$$

Then quantity of water required is: $w/c * P$

$$= 0.6 * 20$$

$$= 12 \text{ lit.}$$

* Based on Required strength of concrete, maximum quantity of water required for 50kg cement is as follows:

M5 → 60 liters of water (w/c = 1.2)
M7.5 → 45 liters of water (w/c = 0.9)
M10 → 34 liters of water (w/c = 0.68)
M15 → 32 liters of water (w/c = 0.64)
M20 → 30 liters of water (w/c = 0.6)

Hot weather Concreting

→ Any operation of concreting done at atmospheric temperature above 40°c.

Effects:

i) Accleserates setting of concrete
ii) Reduction in strength as more w/c ratio is required to maintain workability.
iii) Increase in tendency to crack due to rapid evaporation of water. (ie. plastic shrinkage)
iv) Difficult in control of air in Air-Entrained Concrete

Precautions:

→ The temperature of concrete may be kept as low as possible by shading aggregate and mixture.
→ The temperature of aggregate may be lowered by sprinkling water over them.
→ Rapid hardening is also reduced by working at night.
→ for curing, moisture retaining materials are used.

Cold weather Concreting:

→ Any operation of concreting done at about 5°c atmospheric temperature or below.

Effects:

→ Setting time will be prolonged/delayed.
→ freezing and thawing of concrete at early stage.
→ Hydration will be hampered
→ low workability, workmanship is affected.
→ disruption in strength gaining of freshly placed concrete because of freezing.
→ Improper curing

Precautions:

→ Using hot water
→ Providing enclosure ie. covered area
→ Scheduling concrete
→ Using admixtures accelerators eg. $CaCl_2$
→ Use of type III or high early strength cement ie. Cement containing more C_3S and C_3A.
→ using sufficient amount of cement
→ Concreting shouldn't be done in frozen surfaces.
→ It is preferable to use Rapid hardening cement

Pre-stressed Concrete

→ Pre-stressing is a method in which compression force is applied to the reinforced concrete section.
→ The effect of pre-stressing is to reduce the tensile stress in the section to the point till the tensile stress is below the cracking stress. Thus the concrete does not crack.

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